

## CLAIMS

- 1 1. A method for analyzing an image, comprising:  
2 constructing a graph to represent an object  
3 appearing in the image;  
4 generating a string of symbols corresponding to the  
5 graph; and  
6 processing the string so as to classify the object.
- 1 2. A method according to claim 1, wherein generating  
2 the string comprises generating first and second strings  
3 to represent first and second graphs, respectively, so  
4 that the first and second strings are identical if and  
5 only if the first and second graphs are isomorphic.
- 1 3. A method according to claim 2, wherein the graphs  
2 comprise vertices, and wherein constructing the graph  
3 comprises constructing the first and second graphs so  
4 that the vertices of each of the graphs are arranged in a  
5 specified spatial relation, and wherein generating the  
6 first and second strings comprises constructing the  
7 strings so as to reflect the spatial relation of the  
8 vertices.
- 1 4. A method according to claim 3, wherein constructing  
2 the graph comprises assigning the vertices to represent  
3 respective portions of a contour of a shape of the object  
4 in the image, and arranging the vertices in the specified  
5 spatial relation responsive to relative positions in the  
6 image of the respective portions of the contour.
- 1 5. A method according to claim 4, wherein assigning the  
2 vertices comprises positioning Cartesian coordinate axes  
3 relative to the contour and determining the relative  
4 positions of the portions of the contour with respect to

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5 the axes, and wherein arranging the vertices comprises  
6 positioning the vertices so as to preserve up/down and  
7 left/right relations of the positions of the portions of  
8 the contour.

1 6. A method according to claim 1, wherein constructing  
2 the graph comprises dividing a contour of a shape of the  
3 object in the image into multiple portions, and assigning  
4 vertices of the graph respectively to represent the  
5 portions of the contour.

1 7. A method according to claim 6, wherein dividing the  
2 contour comprises positioning Cartesian coordinate axes  
3 relative to the contour at a plurality of different  
4 orientation angles, and finding the portions of the  
5 contour at each of the angles, and

6 wherein constructing the graph comprises  
7 constructing a plurality of respective graphs in which  
8 the vertices represent the portions of the contour at the  
9 different orientation angles, and

10 wherein generating and processing the string  
11 comprise generating and processing a plurality of strings  
12 corresponding to the respective graphs so as to classify  
13 the shape.

1 8. A method according to claim 6, wherein constructing  
2 the graph comprises constructing a sequence of graphs  
3 that correspond to successively simplified versions of  
4 the contour and accordingly comprise successively  
5 decreasing numbers of the vertices, and

6 wherein generating and processing the string  
7 comprise generating and processing a plurality of strings  
8 corresponding to the graphs in the sequence so as to  
9 classify the shape.

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1 9. A method according to claim 8, wherein processing  
2 the plurality of the strings comprises arranging the  
3 strings as elements of a first vector, indexed according  
4 to the numbers of the vertices in the corresponding  
5 graphs, and computing a measure of distance between the  
6 first vector and a second vector, representing a  
7 reference contour and indexed in like manner to the first  
8 vector, so as to determine a similarity of the shape to  
9 the reference contour.

1 10. A method according to claim 1, wherein the graph  
2 comprises vertices, and wherein generating the string of  
3 symbols comprises performing a depth-first search over  
4 the vertices of the graph, and adding one or more symbols  
5 to the string for each edge encountered in the search.

1 11. A method according to claim 1, wherein processing  
2 the string comprises comparing the string to a reference  
3 string representing a reference object so as to assess a  
4 similarity of the object to the reference object.

1 12. A method according to claim 11, wherein comparing  
2 the string comprises computing a string distance between  
3 the string and the reference string, so as to calculate a  
4 measure of shape difference between the object and the  
5 reference object.

1 13. Apparatus for analyzing an image, comprising an  
2 image processor, arranged to construct a graph to  
3 represent an object appearing in the image, to generate a  
4 string of symbols corresponding to the graph, and to  
5 process the string so as to classify the object.

1 14. Apparatus according to claim 13, wherein the  
2 processor is arranged to generate first and second

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3 strings to represent first and second graphs,  
4 respectively, so that the first and second strings are  
5 identical if and only if the first and second graphs are  
6 isomorphic.

1 15. Apparatus according to claim 14, wherein the graphs  
2 comprise vertices, and wherein the processor is arranged  
3 to construct the first and second graphs so that the  
4 vertices of each of the graphs are arranged in a  
5 specified spatial relation, and to generate the first and  
6 second strings so as to reflect the spatial relation of  
7 the vertices.

1 16. Apparatus according to claim 15, wherein the  
2 processor is adapted to assign the vertices to represent  
3 respective portions of a contour of a shape of the object  
4 in the image, and to arrange the vertices in the  
5 specified spatial relation responsive to relative  
6 positions in the image of the respective portions of the  
7 contour.

1 17. Apparatus according to claim 16, wherein the  
2 processor is arranged to position Cartesian coordinate  
3 axes relative to the contour and to determine the  
4 relative positions of the portions of the contour with  
5 respect to the axes, and to position the vertices so as  
6 to preserve up/down and left/right relations of the  
7 positions of the portions of the contour.

1 18. Apparatus according to claim 13, wherein the  
2 processor is arranged to divide a contour of a shape of  
3 the object in the image into multiple portions, and to  
4 assign vertices of the graph respectively to represent  
5 the portions of the contour.

1 19. Apparatus according to claim 18, wherein the  
2 processor is arranged to position Cartesian coordinate  
3 axes relative to the contour at a plurality of different  
4 orientation angles and to find the portions of the  
5 contour at each of the angles, and is further arranged to  
6 construct a plurality of respective graphs in which the  
7 vertices represent the portions of the contour at the  
8 different orientation angles, so as to generate and  
9 process a plurality of strings corresponding to the  
10 respective graphs for use in classifying the shape.

1 20. Apparatus according to claim 18, wherein the  
2 processor is arranged to construct a sequence of graphs  
3 that correspond to successively simplified versions of  
4 the contour and accordingly comprise successively  
5 decreasing numbers of the vertices, and to generate and  
6 process a plurality of strings corresponding to the  
7 graphs in the sequence for use in classifying the shape.

1 21. Apparatus according to claim 20, wherein the  
2 processor is adapted to arrange the strings as elements  
3 of a first vector, indexed according to the numbers of  
4 the vertices in the corresponding graphs, and to compute  
5 a measure of distance between the first vector and a  
6 second vector, representing a reference contour and  
7 indexed in like manner to the first vector, so as to  
8 determine a similarity of the shape to the reference  
9 contour.

1 22. Apparatus according to claim 13, wherein the graph  
2 comprises vertices, and wherein the processor is arranged  
3 to generate the string of symbols by performing a  
4 depth-first search over the vertices of the graph, and

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5 adding one or more symbols to the string for each edge  
6 encountered in the search.

1 23. Apparatus according to claim 13, wherein the  
2 processor is arranged to compare the string to a  
3 reference string representing a reference object so as to  
4 assess a similarity of the object to the reference  
5 object.

1 24. Apparatus according to claim 23, wherein the  
2 processor is arranged to compare the string by computing  
3 a string distance between the string and the reference  
4 string, so as to calculate a measure of shape difference  
5 between the object and the reference object.

1 25. A computer software product, comprising a  
2 computer-readable medium in which program instructions  
3 are stored, which instructions, when read by a computer,  
4 cause the computer to construct a graph to represent an  
5 object appearing in an image, to generate a string of  
6 symbols corresponding to the graph, and to process the  
7 string so as to classify the object.

1 26. A product according to claim 25, wherein the  
2 instructions cause the computer to generate first and  
3 second strings to represent first and second graphs,  
4 respectively, so that the first and second strings are  
5 identical if and only if the first and second graphs are  
6 isomorphic.

1 27. A product according to claim 26, wherein the graphs  
2 comprise vertices, and wherein the instructions cause the  
3 computer to construct the first and second graphs so that  
4 the vertices of each of the graphs are arranged in a  
5 specified spatial relation, and to generate the first and

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6 second strings so as to reflect the spatial relation of  
7 the vertices.

1 28. A product according to claim 27, wherein the  
2 instructions cause the computer to assign the vertices to  
3 represent respective portions of a contour of a shape of  
4 the object in the image, and to arrange the vertices in  
5 the specified spatial relation responsive to relative  
6 positions in the image of the respective portions of the  
7 contour.

1 29. A product according to claim 28, wherein the  
2 instructions cause the computer to position Cartesian  
3 coordinate axes relative to the contour and to determine  
4 the relative positions of the portions of the contour  
5 with respect to the axes, and to position the vertices so  
6 as to preserve up/down and left/right relations of the  
7 positions of the portions of the contour.

1 30. A product according to claim 25, wherein the  
2 instructions cause the computer to divide a contour of a  
3 shape of the object in the image into multiple portions,  
4 and to assign vertices of the graph respectively to  
5 represent the portions of the contour.

1 31. A product according to claim 30, wherein the  
2 instructions cause the computer to position Cartesian  
3 coordinate axes relative to the contour at a plurality of  
4 different orientation angles and to find the portions of  
5 the contour at each of the angles, and further cause the  
6 computer to construct a plurality of respective graphs in  
7 which the vertices represent the portions of the contour  
8 at the different orientation angles, so as to generate

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9 and process a plurality of strings corresponding to the  
10 respective graphs for use in classifying the shape.

1 32. A product according to claim 30, wherein the  
2 instructions cause the computer to construct a sequence  
3 of graphs that correspond to successively simplified  
4 versions of the contour and accordingly comprise  
5 successively decreasing numbers of the vertices, and to  
6 generate and process a plurality of strings corresponding  
7 to the graphs in the sequence for use in classifying the  
8 shape.

1 33. A product according to claim 32, wherein the  
2 instructions cause the computer to arrange the strings as  
3 elements of a first vector, indexed according to the  
4 numbers of the vertices in the corresponding graphs, and  
5 to compute a measure of distance between the first vector  
6 and a second vector, representing a reference contour and  
7 indexed in like manner to the first vector, so as to  
8 determine a similarity of the shape to the reference  
9 contour.

1 34. A product according to claim 25, wherein the graph  
2 comprises vertices, and wherein the instructions cause  
3 the computer to generate the string of symbols by  
4 performing a depth-first search over the vertices of the  
5 graph, and adding one or more symbols to the string for  
6 each edge encountered in the search.

1 35. A product according to claim 25, wherein the  
2 instructions cause the computer to compare the string to  
3 a reference string representing a reference object so as  
4 to assess a similarity of the object to the reference  
5 object.



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1 36. A product according to claim 35, wherein the  
2 instructions cause the computer to compare the string by  
3 computing a string distance between the string and the  
4 reference string, so as to calculate a measure of shape  
5 difference between the object and the reference object .

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